1.0 EXECUTIVE SUMMARY

The Big Sandy groundwater basin covers an area of approximately 800 square miles in northwestern Arizona. The only inflow to the basin is infiltration from precipitation, primarily along the mountain fronts and stream channels. The primary outflows are to evapotranspiration via riparian vegetation along the river channel, and a small amount of subsurface outflow at Granite Gorge at the southern end of the basin. Current consumptive groundwater uses include small-volume irrigation and public supply wells in the southern part of the basin and pumping in the north to supply the Phelps Dodge Bagdad mine.

The purpose of the groundwater model analysis is to create an understandable and technically sound groundwater flow model adequate for use in evaluating the long-term potential impact of the proposed Big Sandy Energy Project on the groundwater and surface water resources of the Big Sandy basin. The model analysis was prepared for, and conducted under the direction of, the Western Area Power Administration (Western) and Bureau of Land Management (BLM), Kingman Field Office, for their use in preparing the environmental impact statement (EIS) for the Big Sandy Energy Project. The U.S. Geological Survey's (USGS) model MODFLOW, as embedded in Visual MODFLOW, was used for this analysis.

Ongoing peer review of model input data, assumptions, calibration, and predictions was provided throughout the project by URS Denver modeling group staff, URS Phoenix project management staff, EIS preparation staff, and the following team of hydrologists and other resource specialists (hydrology team) drawn from cooperating agencies and their consultants, and project proponent staff and their consultants:

Andrew Hautzinger, U.S. Fish and Wildlife Service
Annette Morgan, Hualapai Tribe
Bob Orr, Western
Cisney Havatone, Hualapai Tribe
Cortney Brand, URS Corporation
Dale Mason, Arizona Department of Water Resources
Dave Carr, URS Corporation
David Schafer, David Schafer & Associates
Don Bay, Hualapai Tribe, Office of Natural Resources
Greg Beatty, U.S. Fish and Wildlife Service
Gwen Knadel, URS Corporation
Joanna Moreno, URS Corporation

Lin Fehlmann, BLM
Marc Sydnor, Greystone Consultants
Paul Manera, Manera Inc.
Paul Summers, BLM

The hydrology team conferred more than 10 times during the course of the modeling work. Modeling plans, framework, assumptions, input data, calibration results, predictive cases, sensitivity cases, and results were discussed and revised in response to these meetings. At several points in this report references are made to points of discussion from this group. This report was reviewed by the members of the hydrology team prior to submittal. Data sources included 12 months of field investigations by the project proponent, including installation of eight monitor wells in multiple aquifers, four geologic test holes, aquifer testing, monitoring of water levels and spring flow rates, isotope sampling, vegetation mapping, and water balance preparation. Other basin-specific data included an assessment of the basin water resources by USGS (Davidson 1973), spring mapping and Big Sandy River flow measurements by the BLM, geologic and water level information from the Arizona Department of Water Resources (ADWR) well database, and river flow data from the USGS.

Subsurface lithologic data obtained from drilling at the Caithness Big Sandy site, and logs from U.S. Department of Energy (DOE) wells (Lease 1981), indicate that there are five hydrogeologic units in the southernmost part of the basin: (1) arkosic gravel at depth beneath most of the basin, (2) a volcanic lower aquifer which is confined and under a substantial amount of artesian pressure; (3) a middle aquifer composed of conglomerate (lower basin fill) that is also confined; (4) a lacustrine (lakebed clay) deposit that serves as an aquitard, and (5) an upper aquifer that includes the recent alluvial deposits of the Big Sandy River (upper basin fill). The volcanic aquifer pressures are maintained by an aquitard surrounding the aquifer. Although almost all of the subsurface data are concentrated in the vicinity of the site, the areal extents of these units were extrapolated using subsurface lithologic data from six deep exploration wells logged by DOE (Lease 1981).

The geology of the site was simplified into a seven-layer framework for the purpose of modeling analyses. In descending order, the layers are as follows:

- upper basin fill (upper aquifer)
- lakebed clays (where present)
- lower basin fill (middle aquifer)
- aquitard above volcanic aquifer

- volcanic (lower)aquifer
- aquitard below volcanic aquifer
- arkosic gravel

The layers all overlie essentially impermeable granitic gneiss.

Current conditions were used to calibrate the model. Groundwater levels, basin-wide flow balance, spring discharge rates, river discharge rates, and responses to pumping were used to assess the validity of the calibration. A transient calibration was undertaken using the aquifer pumping test data. Predicted drawdowns during pumping and recovery phases of the pumping test were used to evaluate the model.

The following uncertain input parameters key to the analysis of impacts were identified in hydrology team meetings:

- aquitard hydraulic properties
- specific yield of volcanic aquifer
- extent of volcanic aquifer near Granite Gorge

In addition, four other parameters were tested when they were found to affect predicted impacts:

- the effect of assuming different lateral extents for the lakebed clay unit
- the effect of assuming a larger longitudinal extent of lakebed clay
- the effect of different recharge rates into the volcanic aquifer (1.35 to 1.85 in/yr)
- the effect of a three-fold smaller assumed evaporation rate at the marsh.

The base case of the groundwater model predicts that, as a result of 40 years of pumping groundwater at the maximum proposed annual pumping rate of 3,000 gpm, the maximum groundwater level drawdown from the project would be 85 ft in the lower (volcanic) aquifer, less than 4 ft in the middle aquifer, and less than 0.5 ft in the upper aquiferThe predicted area of drawdown in the upper aquifer is in the vicinity of the Denton well and Banegas Ranch well No. 2. The base-case model also predicts:

- approximately 1 percent (12 gpm or 19 ac-ft/yr) reduction in the flow out of the Big Sandy basin at Granite Gorge

- approximately 0.2 percent (17 gpm or 27 ac-ft/yr) reduction in outflow as evapotranspiration
- approximately 2.5 percent (142 gpm or 229 ac-ft/yr) reduction in outflow at the marsh near the Denton well as a result of 40 years of pumping

These flow reductions add to a predicted maximum drop in flow rates to the river alluvium of approximately 0.5 percent (171 gpm or 275 ac-ft/yr).

For each of the sensitivity analysis groundwater model runs, a different model parameter (such as specific yield or hydraulic conductivity) was altered. Most of the sensitivity analyses produced results that were consistent with the aquifer test results and an acceptable model calibration, but some did not, and these cases were judged to be unrealistic. Of all of those model run cases that were consistent with the aquifer test results and observed heads at the site, and therefore judged to be feasible, one run showed a maximum predicted groundwater level drawdown in the upper aquifer from the project (after 40 years of pumping groundwater at the same maximum proposed annual pumping rate of 3,000 gpm) was approximately 85 ft in the volcanic (lower) aquifer, 12 ft in the middle aquifer, and less than 1 ft in the upper aquifer. For this worst case, the model also predicted:

- approximately 2 percent (23 gpm or 37 ac-ft/yr) reduction in the flow of water out of the Big Sandy basin at Granite Gorge
- approximately 0.3 percent (33 gpm or 53 ac-ft/yr) reduction in outflow from evapotranspiration
- approximately 5 percent (315 gpm or 508 ac-ft/yr) reduction in outflow at the marsh near the Denton well as a result of 40 years of pumping

These flow reductions add to a predicted maximum drop in flow rates to the river alluvium of approximately 1 percent (371 gpm or 598 ac-ft/yr).

The minimum (best case) predicted groundwater level drawdown from the project was approximately 65 ft in the lower (volcanic) aquifer, less than 0.5 ft in the middle aquifer, and less than 0.1 ft in the upper aquifer, with no reduction in the flow of water out of the Big Sandy basin at Granite Gorge as a result of 40 years of pumping.

The predicted drawdowns in the upper aquifer, and flow reductions, are predicted to be mitigated by water replenishment that matches in volume, timing, and duration the predicted drops in flow rates to the marsh near the Denton well and Granite Gorge.

The volcanic aquifer is predicted to take about 130 years for 90 percent recovery to pre-pumping heads. Observed heads in the volcanic aquifer during actual pumping will demonstrate which of the predicted cases best represents reality, and the corresponding likely water replenishment volumes required for mitigation .